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दूर नियंत्रण उपस्कर तथा तंत्र

भाग 1 सामान्य आकलन

अनुभाग 1 सामान्य सिद्धान्त

Indian Standard

TELECONTROL EQUIPMENT AND SYSTEMS

PART 1 GENERAL CONSIDERATIONS

Section 1 General Principles

ICS 33.200

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

January 1999 **Price Group 10**

Power Systems Control and Associated Communications Sectional Committee, LTD 25

NATIONAL FOREWORD

This Indian Standard which is identical with IEC 870-1-1 (1988) 'Telecontrol equipment and systems — Part 1 : General considerations — Section 1 General principles' issued by the International Electrotechnical Commission (IEC) was adpoted by the Bureau of Indian Standards on the recommendation of Power Systems Control and Associated Communications Sectional Committee (LTD 25) and approval of the Electronics and Telecommunication Division Council.

The text of the IEC standard has been approved as suitable for publication as Indian Standard without deviations.

> Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

CROSS REFERENCES

In this Indian Standard, the following International Standards are referred to. Read in their respective places the following :

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 50 (371) : 1984 International Electrotechnical Vocabulary (IEV) — Chapter 371 : Telecontrol	IS 1885 (Part 50) : 1985 Electrotechnical vocabulary : Part 50 Telecontrol (*first revision*)	Technically Equivalent
IEC 870-1-2 : 1989 Telecontrol equipment and systems — Part 1 : General considerations — Section 2 Guide for specifications	IS 12746 (Part 1/Sec 2) : 1993 Telecontrol equipment and systems : Part 1 General considerations, Section 2 Guide for specifications	Identical
IEC 870-1-3 : 1990 Telecontrol equipment and systems — Part 1 : General considerations — Section 3 Glossary	IS 12746 (Part 1/Sec 3) : 1993 Telecontrol equipment and systems : Part 1 General consideration, Section 3 Glossary	do
IEC 870-2-1 : 1987 Telecontrol equipment and systems — Part 2 : Operating conditions — Section 1 Environmental conditions and power supplies	IS 12746 (Part 2) : 1989 Telecontrol equipment and systems : Part 2 Environmental conditions and power supplies	Technically Equivalent
IEC 870-3 : 1989 Telecontrol equipment and systems — Part 3 : Interfaces (Electrical characteristics) — Specifications	IS 12746 (Part 3) : 1995 Telecontrol equip ment and systems : Part 3 Interfaces (Electrical-characteristics) — Specifications	Identical
IEC 870-4 : 1990 Telecontrol equipment and systems — Part 4 : Performance requirements	IS 12746 (Part 4) : 1993 Telecontrol equipment and systems : Part 4 Performance requirements	do
IEC 870-5 : 1993 Telecontrol equipment and systems — Part 5 : Transmission protocols	IS 12746 (Part 5) : 1992 Telecontrol equipment and systems : Part 5 Transmission protocols	do

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard.

Indian Standard

TELECONTROL EQUIPMENT AND SYSTEMS

PART 1 GENERAL CONSIDERATIONS

Section 1 General Principles

INTRODUCTION

Telecontrol systems serve for monitoring and control of processes which are geographically widespread. They include all equipment and functions for acquisition, processing, transmission and display of the necessary process information. The performance of a telecontrol system is determined basically by:

1) the data integrity of information transfer, from a source to its destination, and

2) the speed with which information is transferred to its destination.

The data integrity is defined as the unchangeability of an information content from a source to its destination, while the speed of information transfer is measured by the overall transfer time.

The high responsibility which is associated with the transmission of information such as commands and the occurrence of adverse environmental conditions necessitate standards for data acquisition and of data transmission which fulfil stringent requirements of data integrity and transmission efficiency.

It should be noted that although this series of standards has been produced specifically for telecontrol systems used in electrical power systems, they may also be applied to other fields of application, e.g. gas and water supply and distribution, etc.

The aim of these standards is to provide adequate information for correct planning and reliable operation of telecontrol systems. The standards are divided into different parts, listed in Clause 2 of this report.

This part of this series of telecontrol standards is intended to give the user a general survey of the systems and their elements, thus presenting the necessary basic information for a thorough understanding of the following parts of these standards.

1. Scope

This series of standards applies to telecontrol equipment and systems with coded bit serial data transmission for monitoring and control of geographically widespread processes.

2. Object

This series of standards describes configurations and functions of telecontrol systems and of related elements. It defines the functional requirements, logical characteristics and interface conditions of the basic elements and the rules those elements shall follow in co-existing with other elements.

These standards do not define the internal physical characteristics of such elements nor the layout, construction or material used.

The following subjects are outside the scope of these standards:

- ripple control systems;
- properties of transmission channels and local bus (highway) systems for communication between process input/output elements;
- teleprotection and locally automated functions even though they may sometimes be implemented within a telecontrol system.

These standards are subdivided into several parts, which are subdivided into several sections and issued as separate publications bearing the following titles and scopes:

IEC Publication 870-1-1: Part 1: General considerations, Section One - General principles (which constitutes this report)

This report explains the structural elements, configurations and basic functions of telecontrol systems.

It gives an overview of functional elements which contribute to basic structures and possible choice of telecontrol systems configurations.

It deals with functions which are typical for any process to be monitored and controlled but emphasizes the specific problems which characterize geographically widespread processes, such as the dominant influence of telecommunication links with restricted bandwidth and often low signal-to-noise ratio.

However, this report shall only serve as an introduction to the detailed standards and recommendations laid down in Parts 2-5 quoted below.

IEC Publication 870-1-2: Part 1: General considerations, Section Two - Guide for specifications (under consideration)

This Section Two of Part 1 will describe guidelines for planning and defining specifications of telecontrol systems and equipment in order to accommodate individual application demands.

IEC Publication 870-1-3: Part 1: General considerations, Section Three - Glossary (under consideration)

This Section Three of Part 1 will present the specific terms of telecontrol techniques as defined in the International Electrotechnical Vocabulary [IEV] [IEC Publication 50 (371)] as well as other terms which are necessary for the understanding of this series of standards.

IEC Publication 870-2-1: Part 2: Operating conditions, Section One - Environmental conditions and power supplies

This Section One of Part 2 defines the environmental and power supply conditions to which the telecontrol equipment should be designed in order to fulfil its specifications. It establishes classes for different conditions and also defines test procedures.

IEC Publication 870-2-2 will constitute Section Two and it will deal with electromagnetic compatibility as well as corrosive and erosive influences.

IEC Publication 870-3: Part 3: Interfaces (in preparation)

This part will define the interface conditions that have to be met in order to correlate the different pieces of equipment needed to form a telecontrol system and to allow the user to manage such a system.

IEC Publication 870-4: Part 4: Performance requirements (in preparation)

This part will deal with those characteristics that have to be met by telecontrol equipment and systems to accomplish the functions for which they are intended in a continuous, secure and precise manner, and in addition to be flexible enough to accommodate future demands.

IEC Publication 870-5: Part 5: Transmission protocols (in preparation)

This part will describe the functional characteristics of data transmission that shall be met in order to implement a telecontrol system by means of links or networks. Data integrity requirements for information transmission, distinct data formats and transmission methods, which fulfil these requirements, will be defined.

This part will include several sections.

The standards listed above will be completed by additional parts and sections as appropriate.

3. General aspects related to telecontrol systems

The fundamental aspects relating to the operation of geographically widespread processes including the generation and optimum transportation and distribution of a product are very similar for the different kinds of products (e.g. gas, water, oil or electricity). Telecontrol systems employed in the operation of electric power systems have been developed to a very advanced state and often serve as examples for applications in other areas. For this reason, the general aspects relating to the operation of any geographically widespread process are explained in the following sub-clauses by reference where appropriate to the operation of an electric power system.

3.1 *The role of telecontrol systems in power systems operation*

The quality of the power supply, which includes its reliability, depends to a large extent on the existence of a coordinated telecontrol system which assures all the necessary supervisory and control functions. The structure of such a telecontrol system is dictated by the power system's architecture and by the strategy of operation adopted by the user(s). It is in essence a distributed process control system conforming to the hierarchical structure of the geographically widespread power transportation and distribution networks. A typical case of a telecontrol system is depicted in Figure 1, page 25.

A system can, from the operational point of view, service a whole power network or be split up into different levels of responsibility or even into partially or fully independent subsystems.

The local control systems of power stations are usually independent of the power network telecontrol system but certain monitored information is fed from the power stations control systems into the power network telecontrol system. Conversely, certain control information, such as set points for power generation, are transmitted into power stations (e.g. in the case of automatic load/frequency control).

Telecontrol system configurations range from a few point-to-point monitoring and control functions up to multilevel systems covering vast geographic areas. The use of computer technology on all levels of the system allows telecontrol systems and architectures to use distributed intelligence with possibilities of preprocessing information to avoid superfluous data flow. Redundancy is provided for vital functions in order to fulfil specified availability and reliability requirements.

Extended processing functions, such as load/frequency control, security analysis, state estimation and short-term predictive energy management, may be carried out either by a separate real-time computer system or by the telecontrol system itself, according to the choice of the systems architecture.

It has also to be noted that equipment and subsystems are often manufactured by different suppliers and/or stem from different generations of technology. Their integration into telecontrol systems thus creates interface problems which are sometimes difficult to solve.

3.2 *The role of the data transmission system*

One of the important factors which has to be taken into account in the planning stage of a telecontrol system is the specification of the data transmission system.

Private or public communication cables, microwave channels and power line carrier (PLC) are most widely used. Since telecontrol systems have to operate in real-time mode, limitations imposed by the telecommunication channels may heavily impair the overall system efficiency. The implication is restricted bandwidth and hence restricted bit rates to be transmitted under noisy environmental conditions, which cause distortion of transmitted signal elements. Conversely specifications of the overall channels have to be chosen to allow optimization of the overall system performance. The data transmission system has to be considered in this sense as an integrated part of the telecontrol system.

In addition, all transmission equipment located in the vicinity of high voltage equipment such as circuit breakers and isolators, is prone to intermittent high noise levels of the burst type and transient voltages. This is especially true for PLC channels.

The performance requirements and boundary conditions for some telecontrol applications, such as teletripping in transmission line protection, generation/load rejection schemes, etc., where instantaneous response in real-time mode is critical, dictate the permanent direct logical connections between data sources and their destinations. This means that the application of store and forward techniques or packet switching are explicitly prohibited in such systems.

There are however telecontrol functions with less demanding performance requirements which may adopt the general techniques and standards which have been developed for office automation applications. Data exchanges among central stations for regions, districts or even nations may fall into that category.

3.3 *Requirements which determine the design of a telecontrol system*

For detailed information, see IEC Publication 870-4.

3.3.1 *Functional characteristics*

The system shall be designed so that the operators will obtain the correct information on actual operational status from strategic points of the power network and shall be able to respond quickly and accurately.

3.3.2 *Environmental conditions*

The installed equipment has to operate correctly under specified operational environmental conditions. Detailed specifications and a classification of environmental conditions are given in IEC Publication 870-2-1.

3.3.3 *Reliability, availability and security (RAS)*

RAS specifications depend on the particular application, and have to be met by the system and all its functional elements. These include uninterrupted power supplies which generally are not considered as being part of the telecontrol system itself. Electromagnetic compatibility has to receive close attention for all electronic equipment involved in telecontrol systems.

Systems should be laid out to operate in a fail safe mode and component failures should be indicated immediately.

3.3.4 *Maintainability, serviceability and expandability, upwards compatibility*

Means for quick fault indication and location are required together with self-diagnosis of the equipment. Both hardware and software should ensure maintainability and expandability, to cope with successive alteration and expansion of the process. Design improvement and changes of technology and of the methods of operation should also be taken into account. The organization of the software should be such as to permit operational control staff to carry out changes quickly and easily to cater for alterations in the power supply network.

3.4 *Main differences between telecontrol systems and local control systems*

The characteristics which differentiate telecontrol systems from local control systems are:

- The use of telecommunication links under restriction of bandwidth and under noisy environmental conditions, requires optimum trade-offs between transmission speed and reliable information transfer in order to cope with the amount of data to be transmitted and the overall transfer time needed.

- Long distance data transmission links or networks, sometimes composed of different transmission media, create problems with occasional high noise levels. The chosen data transmission protocol has to consider these circumstances. High data integrity rates have to be guaranteed at arbitrary high noise levels, whilst taking account of the fact that information transfer rates decrease gradually with increasing noise.

- Numerous geographically widespread plants (and telecontrol stations) have to be controlled by the same centre.

4. Structures and configurations of telecontrol systems

A system's *structure* is understood as the hierarchic order of the basic elements and their interactions, which constitute and characterize that system.

A system *configuration* is a specified arrangement of telecontrol stations and their interconnections.

4.1 *Interrelation of process network architectures and telecontrol system configurations*

In the planning stage, the system configuration has to be defined and tailored according to the user specifications. The configuration of the process, e.g. of a power grid, with the number of voltage levels involved, the number and geographical locations of power stations, control centres, substations and outstations, determines first of all the layout of the data transmission system which has to interconnect these points.

This strategy may differ from country to country and from utility to utility, being state or privately owned.

Emphasis may be given to monitoring functions, leaving control functions partly or entirely to the local operators in substations but providing means for later upgrading of the system. Full operational facilities for remote monitoring and telecontrol functions may be implemented right from the beginning. Even in relatively simple systems, the monitoring and control functions may be quite complex in order to satisfy the many operational requirements for each hierarchical level of a power network. They may also be influenced by security requirements, statutory regulations and economic considerations. The trend to more power grid tie lines, either at company levels or at national levels, calls for high grade application control functions and hence highly sophisticated telecontrol system structures.

For the sake of reliability and security, telecontrol systems are therefore often subdivided into a number of different levels of responsibility while still maintaining an overall operational transparency.

4.2 *Basic functional modules of a point-to-point telecontrol system*

A simple but typical point-to-point structure, with interfaces to be defined in IEC Publication 870-3 is represented in Figure 2, page 26. This serves to describe and explain briefly the basic functional modules of equipment or subsystems, namely:

- process input/output;
- information processing in the controlled station;
- data transmission;
- information processing in the controlling station;
- operator input/output.

Table I, page 23, represents typical interrelations of these functional modules and possible types of related telecontrol modules and equipment. It should be noted that processing of local and special application functions in the controlled station as well as in the controlling station may be performed either in the telecontrol equipment itself or in separate equipment (i.e. in additional processors or in a process computer) which then has to be linked to the telecontrol equipment by a data bus.

4.3 *Functional software modules*

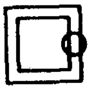
Telecontrol system software can be divided into the categories shown in Table II, page 24.

In typical systems, the basic and application software consist of standard modules. New development work is normally restricted to project specific software.

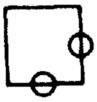
4.4 *Configuration of telecontrol systems*

Data transmission network configurations can be broken down into the basic functional elements listed below, which constitute the basis of all composite network configurations. Details concerning data transmission and traffic methods are dealt with in Clause 6. However, some specific remarks concerning data transmission have to be formulated at this stage. The telecontrol equipment in the control centre usually communicates with more than one outstation and uses more than one link terminal (see Figure 2: DCE, modems, page 26) for this purpose. The number of link terminals used influences the organization of the data transfer.

The various types of data transfer suitable for telecontrol purposes are now illustrated, using the following symbols:

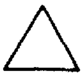


Main control centre

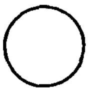


Control centre with one or more link terminals

The small circles inserted into the symbols for stations symbolize the number of link terminals per control centre.



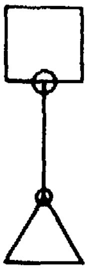
Outstation, controlled station, remote terminal unit (RTU)



Information collecting, concentrating and exchange points

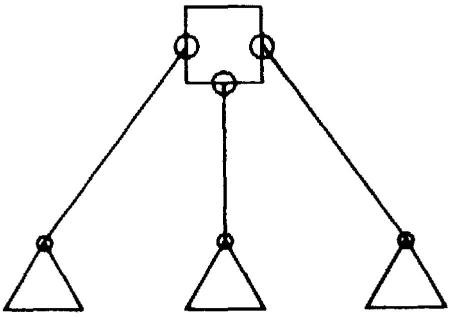
Data transmission line

4.4.1 *Point-to-point configuration*



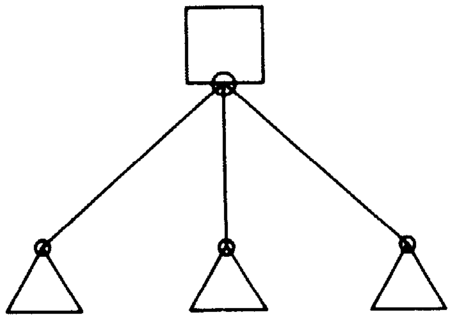
This configuration connects two telecontrol stations and is the simplest type possible

4.4.2 *Multiple point-to-point configuration*



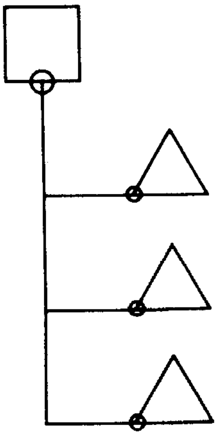
The control centre is connected to the outstations by one link terminal per outstation. At any time, all outstations are allowed to transmit data to the control centre, which in return may transmit messages to one or more outstations simultaneously.

4.4.3 *Multipoint-star configuration*



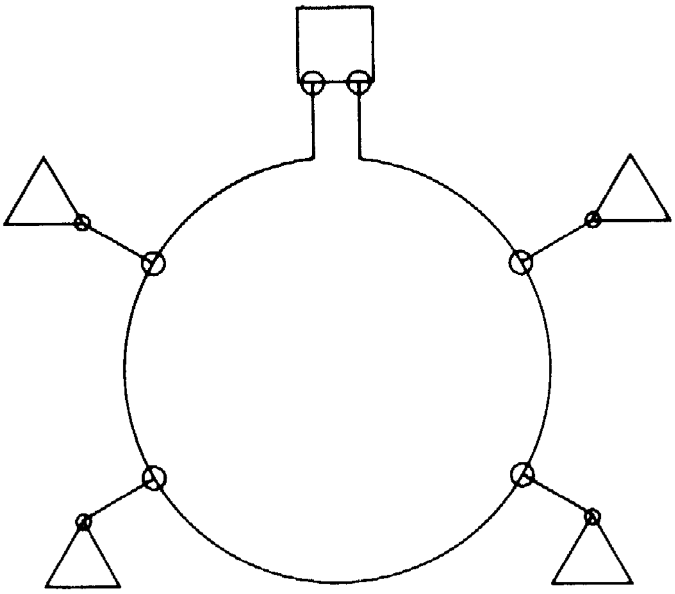
The control centre is connected to more than one outstation by one common link terminal. At any time, only one outstation is allowed to transmit data to the control centre. The central telecontrol equipment may transmit data either to one or more selected outstations or global messages to all outstations simultaneously.

4.4.4 *Multipoint-partyline configuration*



The control centre is connected to more than one outstation by a common path. The restrictions imposed on the exchange between central and outstations is the same as in the multipoint-star configuration (Sub-clause 4.4.3).

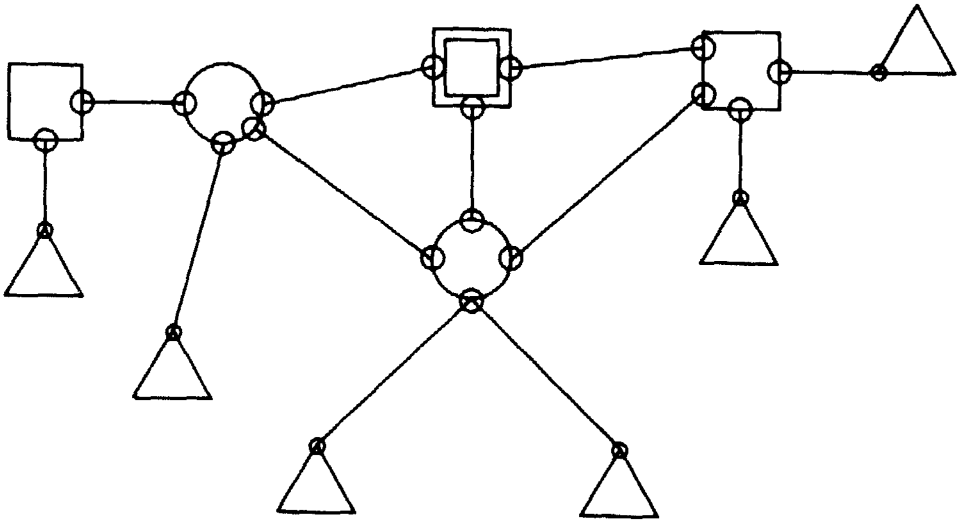
4.4.5 *Multipoint-ring configuration (partyline-ring)*



The communication path between all stations forms a ring. This is a preferred method to improve the availability of the communication path. If the path is interrupted in some location, full communication is maintained, since every station can be reached from two sides of the ring.

4.4.6 *Composite (hybrid) configuration*

Configurations of the types indicated in Sub-clauses 4.4.1 to 4.4.5 can be combined in a great variety of composite configurations. The most important variety is the meshed network configuration in which communication between any pair of stations is required.



Information collection, concentration and exchange points may be inserted.

Multirouting as shown in Sub-clauses 4.4.5 and 4.4.6 increases the reliability and availability of data transmission.

5. Functions of telecontrol systems

5.1 *Layered structure of telecontrol functions*

The functions of data systems may be subdivided into seven layers as specified in the OSI (Open System Interconnection) reference model defined by ISO. This subdivision into modular layers is a useful theoretical model for defining standards. Each layer is essentially independent of the layers below and above it. It treats the layer below as a "service" function and the layer above as a "master" with which it exchanges data and to which it reports errors. It communicates, in general, with its corresponding layer on the other side of the transmission line.

The independence of the layers gives a modularity to the system. It is possible to alter one layer without altering others, in particular some layers may be omitted.

Telecontrol system functions are divided into the following layers:

- *Application functions*

  Cover the special needs of the process to which a telecontrol system is applied, thus dealing with the types of information emanating from the process or from the operator. This information is transferred to the telecontrol system by signals and is handled within this system in the form of data.

- *Operational processing functions including presentation functions*

  Conversion of information into signals and data in the operational equipment.

- *Data transport, network, link and physical transmission functions*

  Application functions and associated operational processing functions are described in general in Sub-clauses 5.2 to 5.4 below. Standards for data transport, network and link functions (such as data format structures) are described in general in Clause 6 below and will be dealt with in detail in IEC Publication 870-5.

5.2 *Application functions*

Application functions are divided into the following two categories:

- Basic functions;
- Extended processing functions.

5.2.1 *Basic functions*

These deal with all types of individual information from and to the process and the operator.

The information content of data resulting from basic application functions remains unaltered while being processed by the telecontrol system (i.e. the data integrity is maintained).

The main subgroups are:

- Monitoring (information acquisition from the process)
  - Teleindication
    discrete state information (single, double or multipoint).
  - Telemetering
    continuous variable quantities.
  - Telecounting
    integrated variables or incremental information.

- Command and control (acting on the process)
    - Telecommand, teleswitching
      single or double commands, pulse type or maintained commands.
    - Teleregulation and teleadjusting
      continuous and discontinuous variable quantities.

5.2.2 *Extended processing functions*

They are derived from a set of basic functions acting on the input and/or output side of the process and operator by means of operational processing functions.

Extended processing functions may alternatively be performed by the CPU of the telecontrol system or by separate computer systems.

Typical examples are (in order of decreasing overall transfer time priority):

- limit indication;
- automatic interpretation of alarms;
- display of faulty states;
- display of summated measured values;
- real time state estimation;
- fault location routines (process and telecontrol system);

- real time event logging for *post mortem* analysis;

- load/frequency control and economic energy management;
- security monitoring and analysis;
- display of integrated metered values;
- short-term energy management;
- contingency evaluation;
- automatic load shedding and restoration;
- hydro-thermal optimization and unit commitment.

5.3 *Operational processing functions*

Operational processing functions ensure correct data acquisition and provide appropriate data presentation. Typical operational processing functions are:

- matching of input/output signals which cross interfaces to man and to the process;
- suppression of contact bounces;
- detection of faulty state information;
- limit checks;
- plausibility checks;
- increment pulse validation;
- calculation of engineering values of measurands;
- summation and other arithmetic operations.

Modern technology allows the economic implementation of additional operational processing functions within stations where information is acquired and within information concentrators. This procedure is called preprocessing. Preprocessed information may also be further processed by the CPU of the controlling station (or a separate computer system).

Preprocessing may also reduce the amount of data to be transmitted and may prevent, particularly in emergency situations, possible overloading of transmission links, the CPU and the man-machine interface.

5.4 *Presentation of the process information to the operator*

The man-machine interface is defined as the shared boundary between the terminal of a data processing system and the operator. The type and form of information to be interchanged between man and machine and the hardware and software to accomplish this have to be specified accordingly.

The basic requirement for optimum man-machine communication is therefore to provide operators and maintenance personnel with adequate and reliable information on the actual status of the power grid and the telecontrol system itself and to make use of central facilities to allow possible intervention in the process.

The types of information mentioned in Sub-clauses 5.2.1 and 5.2.2 are typically displayed by the following hardware:

- *Mimic diagram*
  Represents the topology and indicates the status of the power grid. Active and/or passive elements such as multi-aspect indicators, indication lamps, discrepancy switches, push buttons may be used to display the status and to initiate commands.

- *Operator's console*
  Usually consists of a combination of displays, especially visual display units and keyboards, which provide the operator with detailed information and control facilities.

- *Indicating instruments* (analogue and/or digital)
  For measured and composite values (e.g. sums of analogue values or processed values).

- *Visual display units (VDU)*
  Usually serve for alphanumeric display of alarms, measurands and other information and for graphic display of process network status, etc.

- *Recording equipment*
  For alphanumeric and graphic recording such as teletype, line printers, hardcopying devices and plotters.

- *Acoustic signalization*
  For attracting the operator's attention to dangerous situations.

- *Maintenance equipment*
  For monitoring and maintenance of the telecontrol system itself.

6. Transmission of telecontrol data

6.1 *The role of data transmission standards*

Data transmission standards have been issued by international bodies such as CCITT and ISO. Existing standards are characterized by the fact that they cover commercial type data transmission, i.e. data transfer between scientific or commercial computer systems and remote terminals. Transmission paths may be circuits rented from the public telephone authority, covering distances from a few kilometres up to several hundred kilometres. Data handling of this type is typically optimized for office automation tasks. Message frames and protocols are mostly adequate for the degree of time requirements and data integrity required by those services.

On-line, real-time telecontrol data transmission on the other hand, which is characterized by the fact that telecontrol systems cause material or energy to move, require standards which fulfil stringent data integrity requirements.

The typical requirements of telecontrol data transmission are:

- very high availability;
- very high data integrity;
- short transfer time which allows real-time response to events;
- high information transfer efficiency;
- proper operation in the presence of high electromagnetic interference and differences in earth potential.

The major obstacle in fulfilling these requirements is the fact that the two requirements, "high data integrity" and "low transmission delay", are two conflicting properties in transmission paths with restricted bandwidths and under inimical environmental conditions.

Consequently it is necessary to standardize transmission methods with fair compromises on these two properties.

Utility owned transmission media, such as underground and overhead cables, PLC and microwave links are very often put into operation in order to achieve high availability of the communication links.

6.2 *Data transport, network, link and physical transmission functions*

Data transport functions cover all functions involved in the management of efficient and reliable information transfer between stations.

Requests for the transmission of messages with various priorities, lengths, dialogue types and destinations are accepted from the "application" layer in each station. Appropriate transmission procedures are delegated to the lower protocol layers which report on the successful performance or on observed errors to the higher layers. Automatic recovery procedures are initiated upon dynamic errors, while error reports to the higher layers are generated upon the detection of persistent errors.

Typical functions which are managed in the higher layers in co-operation with the lower protocol layers "link" and "physical transmission" are:

- Priority organization for spontaneous and cyclic information transfers.
- Performance of maintenance and test routines upon request (e.g. activating or deactivating links, stations or system parts).
- Error recovery strategies.
- Generating and monitoring error-detecting codes.
- Generating and monitoring frame synchronization, acknowledgement of message frames and detecting frame size errors.
- Serializing and deserializing of message frames.
- Monitoring signal quality.
- Converting signal levels and data formats.

6.3 *Characteristics of telecontrol data transmission*

6.3.1 *Telecontrol message structure*

The general structure of a telecontrol message is shown in Figure 3, page 27 (for details, see IEC Publication 870-5). Standard frame formats provide information field lengths which may vary only by multiples of octets.

6.3.2 *Transmission initiation modes of telecontrol devices*

Three basic transmission initiation modes are used for telecontrol data transmission:

- *Event initiated transmission (spontaneous transmission)*

  Data transmission is initiated by events in stations where they occur, such as changes of breaker positions, changes of measured values, etc. This method best meets real-time requirements. The proper operation of event initiated transmission is ascertained by transmission of periodic test information ("watchdog" function).

- *Transmission on demand*

  In this case the outstation is requested by the master station to transmit the actual information status. In the case of several outstations this mode is also called interrogative or polling mode.

- *Cyclic transmission*

  This mode is frequently used for transmission of measured values and binary information from outstation to the control station. Sets of measured values and/or binary status information are transmitted in a time division scheme. It has to be noted that cyclic transmission causes a time delay in updating which increases with the amount of information to be scanned in one cycle. A data path is needed in the direction of information flow only.

Event initiated transmission and transmission on demand, where data is transmitted only once, call for transmission with very high data integrity. For the cyclic updating mode, where occasional wrong information is corrected during the following cycle, a lower data integrity class would be sufficient (for details, see IEC Publication 870-5).

6.3.3 *Combinations of transmission initiation modes and dialog procedures*

Link configurations, initiation modes of transmission and types of traffic are principally independent of each other and a multitude of combinations would therefore theoretically be possible. Practical solutions, however, are limited by a series of restrictions imposed mostly by considerations of a partly technical and a partly economical nature.

Combinations of transmission initiation modes are:

- Event initiation and transmission on demand, polled status information from one or more outstations, or a set of specific measured values and/or single-point or double-point status information is scanned during a requested time period, etc.

- Event initiated and cyclic transmission. Cyclic transmission can be interrupted, thus enabling event transmission which has higher priority. Periodically initiated test data transmission may also be used as "watchdog" function.

- Combination of the three transmission initiation modes with the following priority allocation:

  1) event initiated transmission;
  2) transmission on demand;
  3) cyclic transmission.

With regard to network configurations the following points have to be taken into consideration:

- Multiple point-to-point configurations can be broken up into the equivalent number of point-to-point link elements, all having independent link terminals on both ends. All three initiation modes of transmission and combinations thereof can be applied to each link individually. The data flow from *n* outstations will be limited by the throughput of the system's central processors and not by the capacity of the individual link terminals.

  Restrictions in data flow, especially for links with cyclic transmission, are due to the imposed transmission priorities.

- All multipoint configurations, such as star and party line, restrict the possible data transmission rate from *n* outstations to less than 1/*n* per outstation.

Further restrictions are due to the choice of combinations of the three transmission initiation modes and the imposed transmission priorities. It has to be noted that the information handling strategies of multipoint configurations are equal to those of bit-serial data bus systems. Bus systems may operate in different initiation modes and therefore need sophisticated data transmission handling capabilities.

Event initiated transmission may in the case of emergency suddenly cause an increasing amount of information to be transmitted in a short time (of the order of magnitude of 1 or 2 s duration) at one or all outstations. Multiple point-to-point configurations are more flexible in coping with an emergency than multipoint configurations.

6.4 *Types of traffic in transmission channels*

The particular procedures for conveying data over the communication link, together with the direction and the chronological sequence in which communication links may be needed, are functions of the types of traffic carried by the link.

6.4.1 *Simplex traffic*

Simplex (one way) traffic may be used in the cyclic updating mode in point-to-point and multipoint telemonitoring systems or in systems using the channel selecting mode.

6.4.2 *Halfduplex traffic*

Halfduplex traffic is characterized by a transmission link common to both directions, thus precluding simultaneous transmission in both directions. Compared to simplex transmission, it offers enhanced protection of event information against loss by defining appropriate dialogue procedures.

6.4.3 *Duplex traffic*

Independent transmission channels exist for the incoming and outgoing directions, thus representing a four-wire transmission path having the possibility of simultaneous data transmission in both directions.

6.5 *Telecommunication systems*

Properties of telecommunication systems are mentioned in this context only in so far as they serve as a subsystem to a telecontrol system for data transmission.

Transmission of telecontrol data is performed in most countries over fully or partly utility owned information transmission systems. Rented channels from telephone companies are also in use.

The channels usually comprise the following facilities for internal use:

- telephone with private automatic branch exchange (PABX);
- teleprinter, facsimile;
- telecontrol data transmission;
- teleprotection;
- closed circuit video.

Selections of existing transmission standards (CCITT, EIA and others) which fulfil the requirements of telecontrol systems are adopted.

6.5.1 *Transmission media*

The following transmission media are currently in use:

- radio (VHF, UHF);
- point-to-point microwave;
- power line carrier (PLC);

- communication cable embedded in earth wire - suspended communication cable - underground communication cable	multiwire cables, coax cables, optical fibres.

The transmission facilities form a more or less complete telecommunication network. Data transmission rates of telecontrol systems are usually in the range of 50 bits/s to 2 400 bits/s, infrequently as high as 4 800 bits/s and 9 600 bits/s. Signalling speeds in excess of 9 600 bits/s generally require special broadband channels which can be provided using conventional telecommunication transmission techniques over various telecommunication media.

6.5.2 *Transmission methods*

Telecontrol systems rely exclusively on bit-serial binary data formats. The physical representation of the information units (bits) on the transmission path depends on the transmission medium used, on bandwidth limitations, and other environmental conditions.

The most common transmission methods are:

- Pulse code modulation (PCM) in which binary information is represented by two distinct signal levels of fixed duration, in the case of cablebound transmission over short distances (baseband transmission), or by two distinct frequencies of distinct duration for longer distances or other transmission media. In the case of low transmission rates (up to 1 200 bits/s) ordinary "frequency shift" channels are used which convert the two distinct signal levels into two distinct frequencies. For higher transmission speeds various multilevel modulation techniques are applied which require and deliver, in addition to the binary data flow, "signal-element-timing" information and other data control information.

- Digital pulse duration modulation (DPDM) in which binary information is represented by signal pulses of two distinct durations. The number of pulses and pulse intervals represent a given number of bits. Frequency shift channels and modem techniques can be implemented with DPDM and PCM.

6.6 *Protection of messages against noise on the transmission channel*

With regard to telecontrol data transmission and its integrity the following characteristics of specific channel types are of interest:

- available bandwidth per channel;

- planned signal/noise ratio figures which prevail during normal environmental conditions and extremely low signal/noise ratios during intervals of burst type noise;
- attenuation (db/km) and its variations due to external influences (weather, icing, etc.);
- transmission time delay (ms/100 km).

These characteristics are very different for the transmission media cited above and interrelated for specific channel type.

Burst type noise, produced by operation of circuit breakers and isolators, is practically absent on microwave channels, although variations in attenuation due to atmospheric scattering may have to be compensated by diversity operation. PLC on the other hand is characterized by poor signal/noise ratios during the short periods of burst type noise but attenuation per kilometre is low, thus allowing increased repeater spacing.

6.6.1 *Protection of information against falsification*

Measures can be applied in all layers of telecontrol systems to reduce the possibility of information falsification. Examples of typical measures are:

- Improving the signal-to-noise ratio. Passive methods include screening of coaxial cables, proper choice of carrier and subcarrier frequencies. Active methods include increase of the transmitter power, etc.
- By weighted superposition of redundant coding and signal quality supervision (pulse amplitude, signal distortion), maximum reduction of residual (undetected) errors in transmission links can be obtained.

  After error detection, the output of the falsified information has to be suppressed.
- Using plausibility checks, state estimators and extended information transmission procedures (such as "check before operate" for command transmission).

6.6.2 *Protection against loss of information*

Spontaneous telecontrol systems may lose information if the information is discarded after error detection on the transmission path. This can be avoided by different methods such as:

- *Decision feed back*

  Various methods are in use, for example positive acknowledgement and automatic repetition of transmission if the positive acknowledgement does not arrive.

- *Information feed back*

  This method combines error detection with protection against loss of information by performing an identity check between the information sent out and retransmitted to the initiating station.

- *Provision of sequential numbers for subsequent message frames.*

TABLE I

Interrelation of basic functional modules and typical systems functions with typical hardware modules within a telecontrol system

Basic functional modules	Typical (application and telecontrol) systems functions	Type or related modules of equipment
Process input/output - To convert actual physical states of the process into coded data (monitoring direction) - Act on the process (command direction)	*To ensure information transfer* - From sensors in the process to CPU, e.g. to add up and to code metering pulses - From CPU via transducers and actuators to the process	*Process equipment* - Sensors in the process - Input channels receiving (analogue or digital) data from the process - Transducers, actuators in the process, operating valves, circuit-breakers, governors ↕
Specific telecontrol information processing in the controlled station - To process data according to predefined rules	*To process incoming and outgoing information*, e.g. - To detect events by comparison of former and new status information - To reduce data if needed - To react on comparison of set point and measurands by sending an actuator command	*Telecontrol equipment* - Central processor (CPU) - Associated front-end processors - Hard wired logic - Main memory devices - Internal bus subsystems - Input/output channels to process equipment ↕
Data transmission - To transmit serial data between widespread stations of a telecontrol system	*To ensure reliable transmission of all important process information* - Signal (and/or) format conversion - Error detection, e.g. by codes and signal quality monitoring - Data path performance monitoring	*Data circuit-terminating equipment* - Standardized CCITT modems - Special modems, e.g. incorporating channel switching and processing in case of sophisticated communications networks ↕
Specific telecontrol information processing in the controlling station - To process data according to predefined rules	*To process incoming and outgoing information*, e.g. - To prepare clear, comprehensive information for display - To derive automatic commands from information coming from different stations of the telecontrol system	*Telecontrol equipment* - Central processor (CPU) - Associated front-end processors - Hard-wired logic (very rarely) - Main memory devices (Core, IC) - Auxiliary mass storage (disk, tape) - Internal bus subsystem - Input/output channels ↕
Operator's input/output - Information display and recording - To provide means for interacting with the process by operators - To provide means for online testing and fault diagnosis of the telecontrol system itself	*To convert data into information comprehensible by personnel and to convert human actions into data* - Indication alarm and record functions on/off status - Digital and analog metering - Control and command functions - Supervisory alarm functions - Fault diagnosis	*Operator's equipment* - Mimic diagram - Visual display (VDU) - Signalling lamps - Recorders, line printers, data loggers - Analog and digital indicating instruments - Process operator consoles, keyboards - Discrepancy (control) switches - Light pen, trace ball or joystick for VDU

Note. – The mark ↕ indicates that the related hardware equipment need not necessarily coincide fully with the basic functional modules.

TABLE II

Typical functional software modules of telecontrol systems

TELECONTROL SYSTEMS SOFTWARE

BASIC SOFTWARE	STANDARD APPLICATION SOFTWARE	PROJECT SPECIFIC SOFTWARE	DATA BASE
application independent	system independent	project dependent	system dependent
- Operating system	- Telecommunication and interprocessor communication	- Particular functions of of a system (e.g. arithmetic procedures for analogue values)	- System control tables
- Hardware drivers	- Man-machine dialogue		- Tables for object descriptions (software modules
- Time and mathematical basic functions	- Data input/output programs		- Object status tables (process state)
- Programs for maintenance and tests	- Data processing and control programs		
	- Data logging, display and long time storage programs		- Data base maintenance software
	- Data base management		

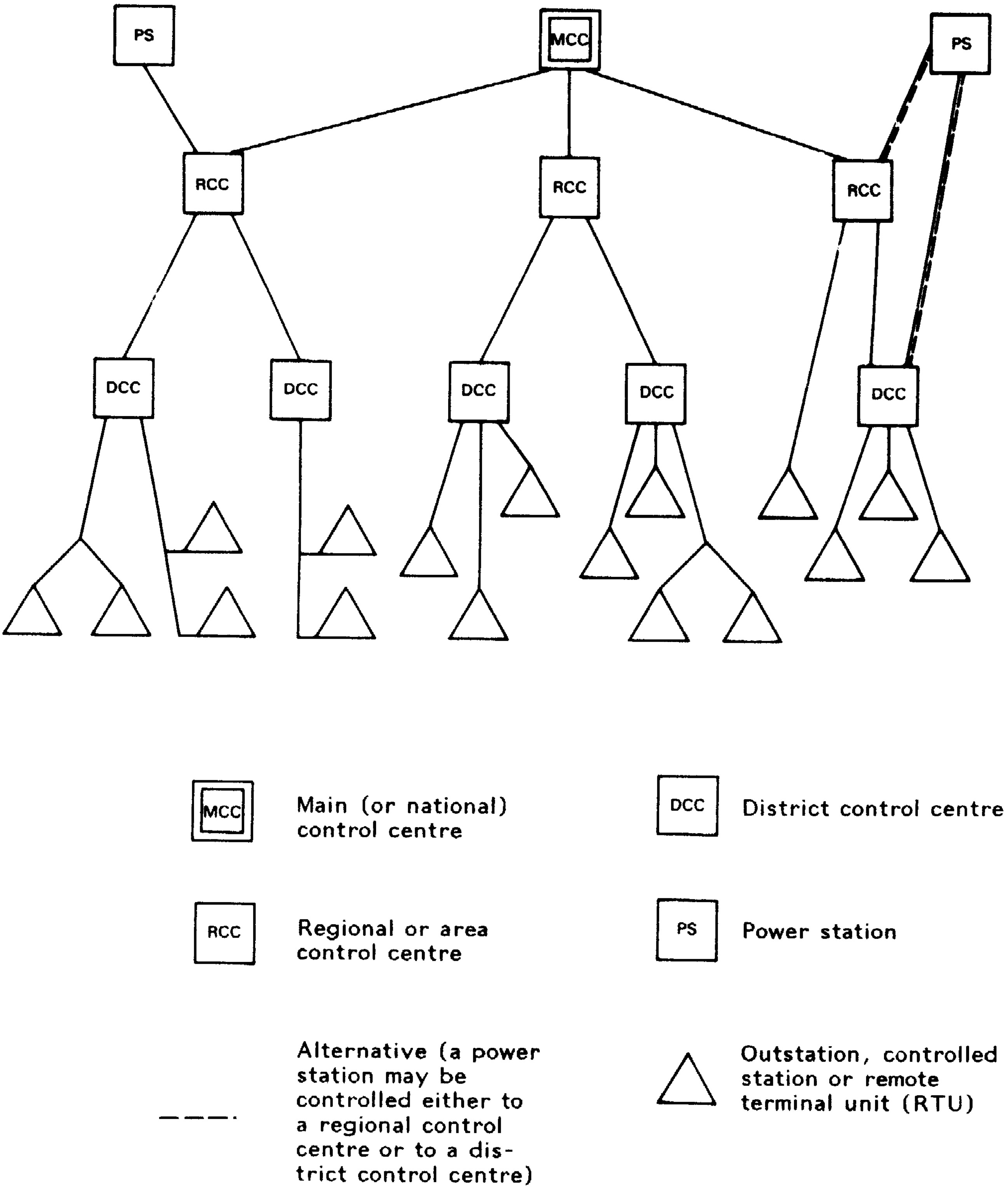
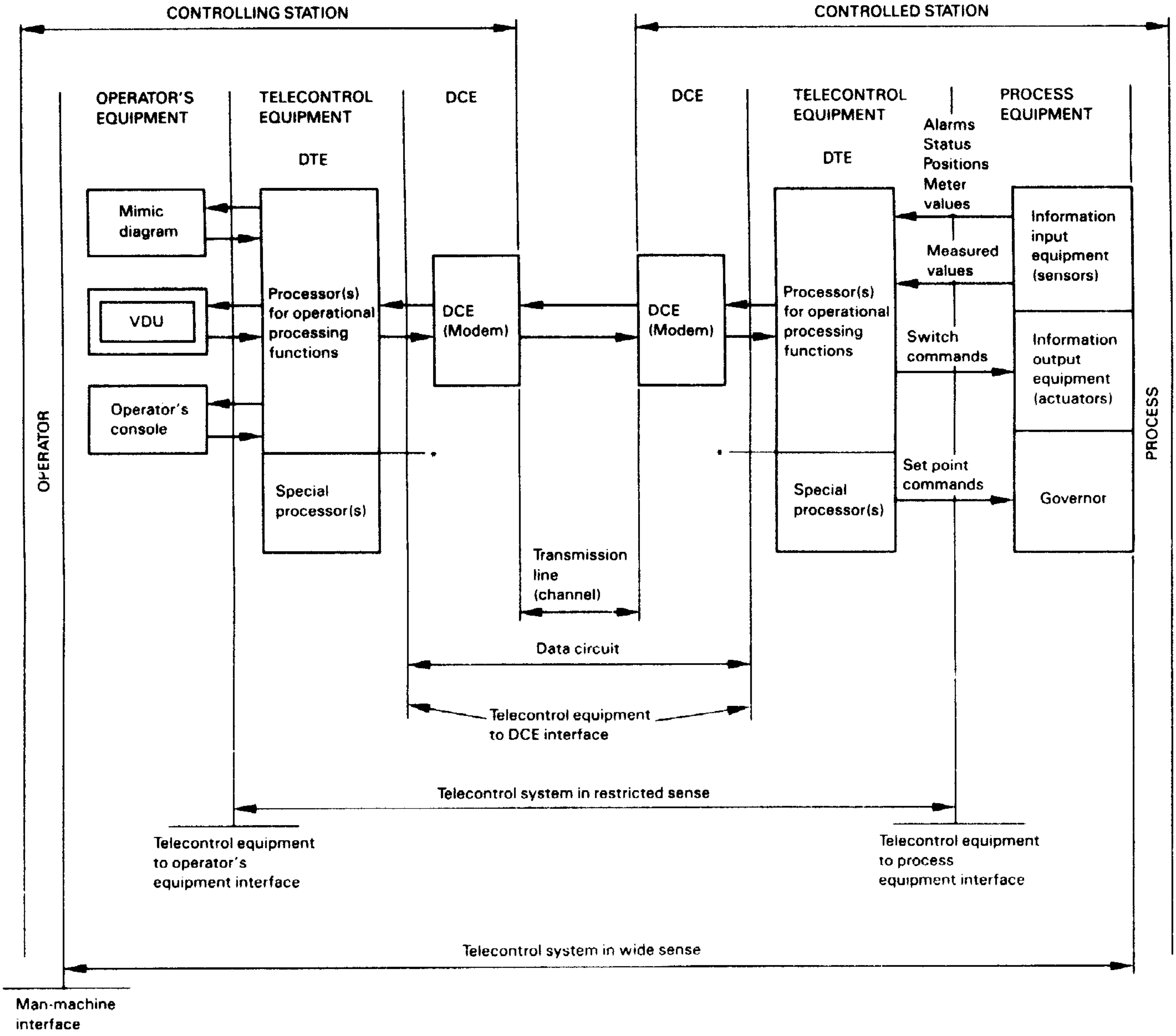

PS
MCC
PS
RCC
RCC
RCC
DCC
DCC
DCC
DCC
DCC
MCC
Main (or national) control centre
DCC
District control centre
RCC
Regional or area control centre
PS
Power station
Alternative (a power station may be controlled either to a regional control centre or to a district control centre)
Outstation, controlled station or remote terminal unit (RTU)

Fig. 1. - Typical hierarchical structure of a telecontrol system for power transportation and distribution network.


CONTROLLING STATION
CONTROLLED STATION
OPERATOR'S EQUIPMENT
TELECONTROL EQUIPMENT
DTE
DCE
DCE
TELECONTROL EQUIPMENT
DTE
PROCESS EQUIPMENT
Alarms
Status
Positions
Meter values
Measured values
Switch commands
Set point commands
Mimic diagram
VDU
Operator's console
Processor(s) for operational processing functions
Special processor(s)
DCE (Modem)
DCE (Modem)
Processor(s) for operational processing functions
Special processor(s)
Information input equipment (sensors)
Information output equipment (actuators)
Governor
OPERATOR
PROCESS
Transmission line (channel)
Data circuit
Telecontrol equipment to DCE interface
Telecontrol system in restricted sense
Telecontrol equipment to operator's equipment interface
Telecontrol equipment to process equipment interface
Telecontrol system in wide sense
Man-machine interface

VDU: Visual display unit
DCE: Data circuit-terminating equipment
DTE: Data terminal equipment
* Optional interface between telecontrol processor(s) and special processor(s)

Fig. 2. - Typical structure of a telecontrol system (shown by a point-to-point configuration).

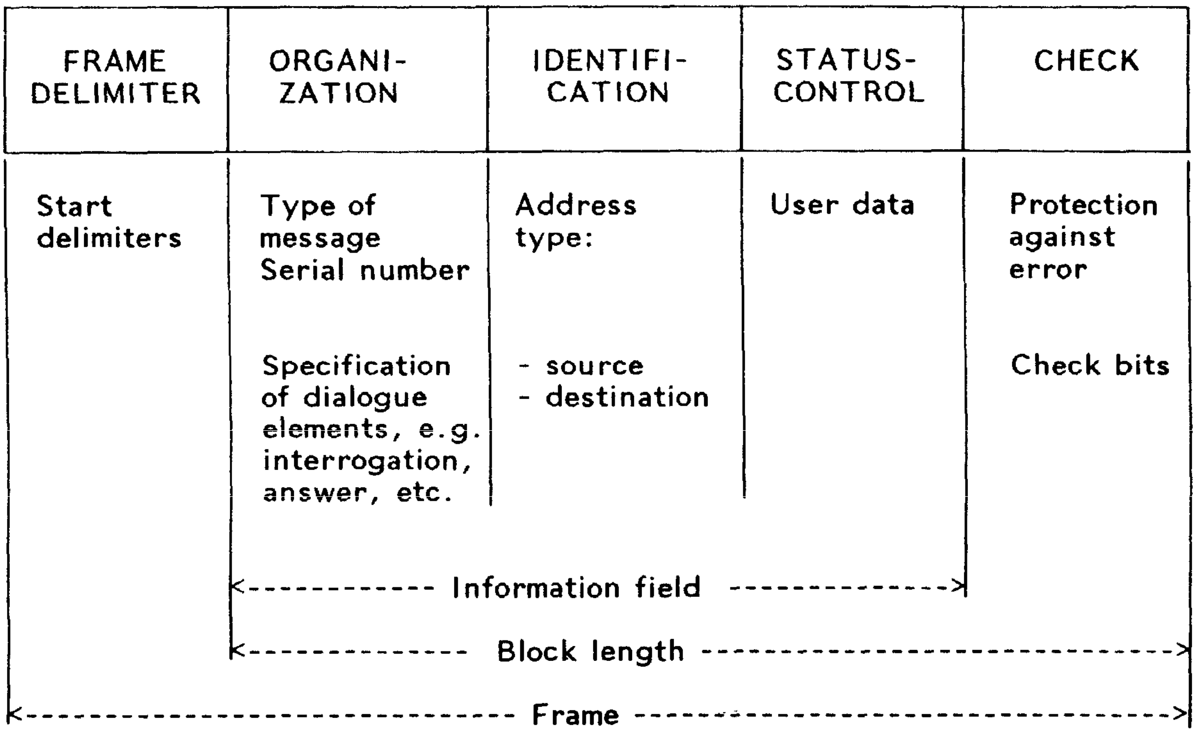


Fig. 3.- General structure of a telecontrol message

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This Indian Standard has been developed from Doc : No. LTD 25 (965).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at New India Printing Press, Khurja, India